ARMY RESEARCH LABORATORY

Dynamic Punch Shear Behavior of Unidirectional and Plain Weave S-2 Glass/SC15 Composites

by Libo Ren, Bazle A. Gama, John W. Gillespie Jr., and Chian-Fong Yen

ARL-CR-535   **March 2004**

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5069

ARL-CR-535   **March 2004**

Dynamic Punch Shear Behavior of Unidirectional and Plain Weave S-2 Glass/SC15 Composites

Libo Ren, Bazle A. Gama, and John W. Gillespie Jr.
University of Delaware Center for Composite Materials

Chian-Fong Yen
Materials Sciences Corporation

Approved for public release; distribution is unlimited.

Report Documentation Page		*Form Approved* *OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
March 2004	Final	June 2002–July 2003

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Dynamic Punch Shear Behavior of Unidirectional and Plain Weave S-2 Glass/SC15 Composites	DAAD19-01-2-0005
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)	5d. PROJECT NUMBER
Libo Ren,[*] Bazle A. Gama,[*] John W. Gillespie Jr.,[*] and Chian-Fong Yen[†]	
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
[*]University of Delaware Center for Composite Materials, Newark, DE 19716 [†]Materials Sciences Corporation, Fort Washington, PA 19446	

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
U.S. Army Research Laboratory ATTN: AMSRD-ARL-WM-MB Aberdeen Proving Ground, MD 21005-5069	
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)
	ARL-CR-535

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Dynamic punch shear behavior of unidirectional and plain weave S-2 Glass/SC15 epoxy composites is presented. An incident bar and a transmission tube assembly in compression split-Hopkinson Bar setup is used for the dynamic punch shear study. Dispersion correction methodology is used with "3-wave" analysis to convert the experimental bar data into dynamic load-displacement curves. A methodology for determining the average transverse shear strength of the composite laminates is described. The average transverse shear strength of unidirectional and plain weave composites as a function of displacement is presented.

15. SUBJECT TERMS
wave dispersion, split-Hopkinson Pressure Bar experiment, cylindrical tubes

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Libo Ren
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED	UL	36	19b. TELEPHONE NUMBER *(Include area code)* 302-831-0248

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

Acknowledgments

INTENTIONALLY LEFT BLANK.

1. Introduction

Transverse impact and penetration of fiber-reinforced composites are important in personal protection systems, composite armor, marine, automotive, and aerospace structures. Composite materials absorb impact energy through unique macro- and micro-damage mechanisms. Examples of damage include delamination and debonding between layers and woven tows, out-of-plane fiber shear, hydrostatic crush, fiber breakage, pull-out, and frictional sliding at the fiber matrix interphase due to tension and bending deformations as well as matrix plasticity and cracking. Different impact damage modes of composite laminates under partial and complete penetration of S-2 Glass[*]/SC15 Composite laminates are presented in figures 1 and 2. The penetration resistance or ballistic limit of a composite laminate is often expressed by the ballistic limit velocity, V_{50}. The energy absorbed by the composite laminate per unit weight of the projectile, e_A, is given by

$$e_A = \frac{V_{50}^2}{2}.$$

(1)
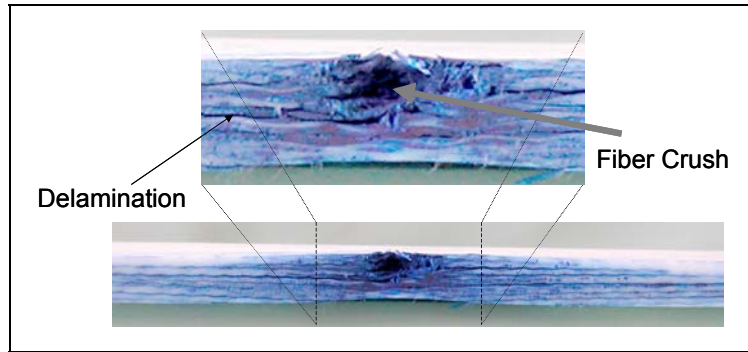
Figure 1. Partial penetration of S-2 Glass/SC15 Composites.

Researchers have investigated the impact damage and penetration of composite laminates and reported the ballistic limit velocities (*1–10*). It has been shown that there are similarities between ballistic impact damage and quasi-static punch shear damage of composite laminates, and efforts have been undertaken to model the ballistic limit of composite laminates using quasi-static punch shear experimental load-deflection curves (*1, 2*). Recent research by the authors (*11*) have identified that energy absorption during punch can be used for relative ranking of composite materials. It has also been identified that the damage modes in quasi-static punch shear depends on the punch to support diameter ratio, $SPR = D_S/D_P$, where D_S and D_P are the diameters of the support and punch, respectively. If, $SPR = D_S/D_P \approx 1$, the damage of the

---

[*]S-2 Glass is a registered trademark of Owens Corning.

Figure 2. Complete penetration of S-2 Glass/SC15 Composites.

composite laminate is predominantly due to transverse shear. The objective of this study is to characterize the transverse fi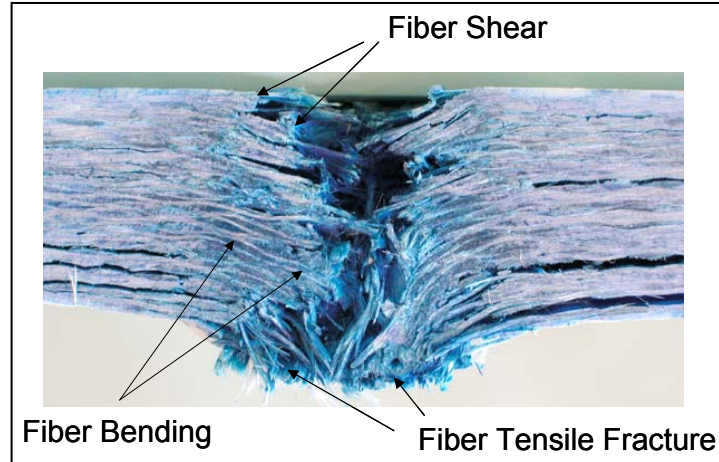ber shear strength of S-2 Glass/SC15 epoxy composites under dynamic loading conditions. The transverse fiber shear strength of composite laminates is one of the two important parameters of a recent composite damage model, MAT_COMPOSITE_DMG_MSC, implemented in LS-DYNA for impact and penetration modeling.

2.   Experimental

2.1   Setup

The transverse fiber shear strength of unidirectional and plane weave S-2 Glass/SC15 epoxy composite laminates is experimentally determined under dynamic punch shear loading conditions. Dynamic punch shear tests are usually performed in a compression split-Hopkinson Pressure Bar (SHPB). The analysis of the dynamic punch shear test using a transmission tube and plate specimen is simple and is chosen as the experimental technique for this research effort. The description of this test method is described next.

The dynamic punch shear test is performed using the SHPB apparatus at the University of Delaware–Center for Composite Materials (UD–CCM). A schematic drawing of the test setup with nomenclature is shown in figure 3. The SHPB dynamic punch shear apparatus consists of an incident bar (IB) and a transmission tube (TT). The inner diameter of the TT is slightly greater than the IB diameter, such that the IB bar can punch through the composite specimen (SP) sandwiched between the IB and TT.   A striker bar (SB), powered by the high-pressure gas, impacts the pulse shaper (PS) placed on the impact face of the IB. Depending on the type of pulse shaper used, a compressive stress pulse is produced in the IB. The stress pulse propagates
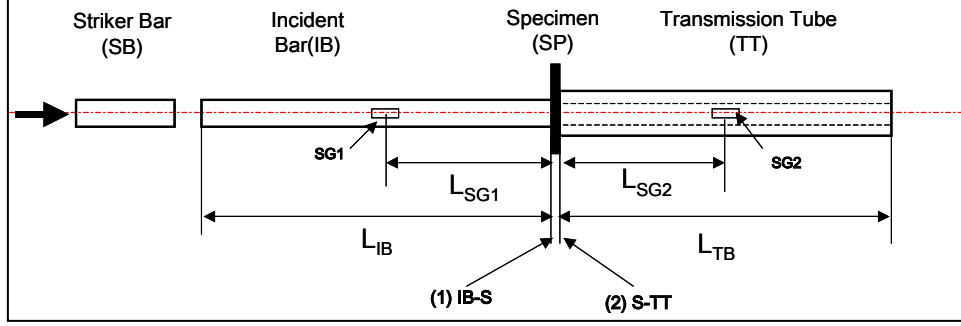
Figure 3. Dynamic punch shear test setup.

along the IB and reaches the incident bar-specimen (IB-S) interface. There, a portion of the energy contained in the pulse will be transmitted to the TT through the specimen while shearing it and the rest will be reflected back into the IB. The propagating stress pulses are measured through strain gages (SGs) mounted on the surface of the IB and TT.

Different dimensions of the present experimental setup are as follows: L_{IB} = 1653 mm, L_{TB} = 762 mm, L_{SG1} = 823 mm, and L_{SG2} = 327 mm. The diameter of the IB is D_{IB} = 14.4 mm. The outer diameter of the TT is D_{TT}^{OD} = 25.4 mm and the inner diameter of the TT is D_{TT}^{ID} = 15.2 mm. The diameter of the SB is D_{SB} = 13.1 mm. The SB has a length of L_{SB} = 305 mm.

Both the IB and the TT are made of Inconel C-276. The density is 8.89 g/cm^3 the Young's modulus is 205 GPa, and the Poisson's ratio is 0.307. The resistance and gage factor of the SGs (SG1 and SG2) (CEA-06-125UT-350, Micro-Measurements, Inc.) are 350 Ohms and 2.115, respectively. A data acquisition system written in LabView is used to collect the experimental data from the SGs. The sampling rate of the data acquisition system is 5 mega samples/s, which corresponds to a time interval between two consecutive data points of 0.2 μs.

2.2   Data Reduction

From the SG on the IB, the incident strain pulse, ε_i (t), and the reflected strain pulse, ε_R (t), are recorded. From the SG on the TT, the transmitted strain pulse, ε_{TT} (t), is recorded. These strain data can then be converted to stress in the bars, σ_i (t), where the subscript i stands for I, R, and TT. The strain data measured at the SG locations are dispersion corrected and time shifted to the bar-specimen interfaces following a dispersion-correction methodology developed by the authors (12, 13). The dispersion correction methodology described by Lifshitz and Leber (14) is used to determine the correct longitudinal wave velocity in the IB. The dispersion correction of the transmission tube is performed by solving the frequency equation developed by Mirsky and Herrmann (15, 16) and the dispersion algorithm developed by the authors (13). The dispersion corrected and time shifted data to the bar-specimen interfaces can then be used to compute the displacement and forces at those interfaces following a one-dimensional (1-D) wave propagation analysis. Figure 4 shows the notations used in the present analysis.
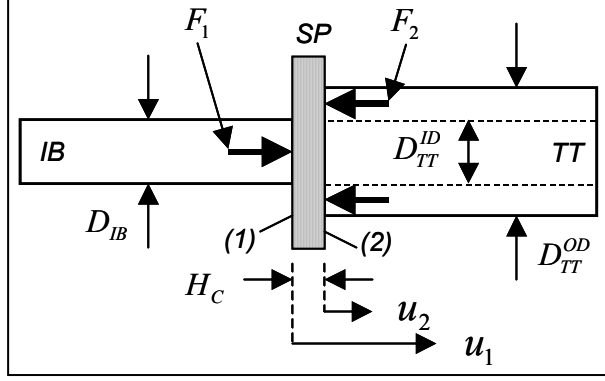
Figure 4. Definition of displacements and forces at the
bar-specimen interfaces.

The displacement and the force at the IB-S (1) interface are defined as u_1 and F_1; and the displacement and the force at the S-TT (2) interface are defined as u_2 and F_1. The displacements at the bar-specimen interfaces can be expressed as follows:

$$u_1(t) = -\int c_0^{IB} \cdot (\varepsilon_I(t) - \varepsilon_R(t))\,dt, \tag{2}$$

and

$$u_2(t) = -\int c_0^{TT} \cdot \varepsilon_T(t)\,dt, \tag{3}$$

where c_0^{IB} and c_0^{TT} are the corrected/calibrated wave speed of IB and TT following the dispersion-correction methodology. The average displacement of the specimen is defined as

$$u_S(t) = \delta(t) = u_2(t) - u_1(t). \tag{4}$$

The displacement rate is defined as

$$\dot{\delta} = d\delta/dt. \tag{5}$$

The forces acting on the bar-specimen interfaces are defined as follows:

$$F_1 = A_{IB} \cdot E_{IB}^{Corr} \cdot (\varepsilon_I(t) + \varepsilon_R(t)), \tag{6}$$

and

$$F_2 = A_{TT} \cdot E_{TT}^{Corr} \cdot \varepsilon_T(t), \tag{7}$$

where A_{IB} and A_{TT} are the area of the cross section of the IB and TT, respectively. E_{IB}^{Corr} and E_{TT}^{Corr} are the corrected Young's modulus of the two bars after calibration, respectively. The average force acting on the specimen can then be expressed as follows:

$$F_S = (F_1 + F_2)/2. \tag{8}$$

The average dynamic force-displacement curve can then be plotted using equations 4 and 8. The average shear stress can be determined by considering the dimensions of the specimen as in

figure 5, where D_M is defined as the average of punch diameter D_P and tube inner diameter D_S. The thickness of the plate sample is given by H_C. The average shear stress can then be expressed as follows:

$$\tau = F_S / \pi D_M H_C.$$ (9)
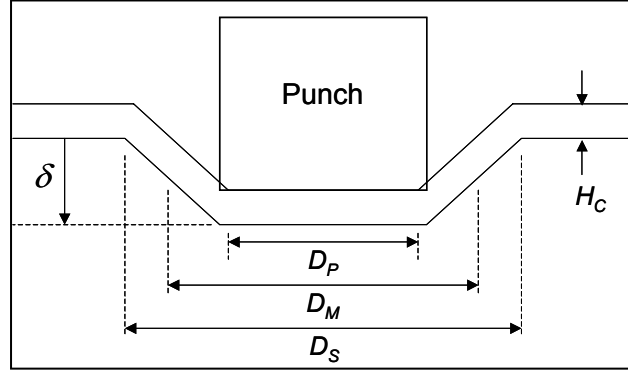
Figure 5. Nomenclatures for the punch shear specimen.

3.   Materials

Composite laminates are made from unidirectional S-2 Glass fibers, and 5 × 5 plain weave S-2 Glass fabric preforms (0.81 kg/m², 24 oz/yd²) with API SC15-toughened epoxy resin using vacuum-assisted resin transfer molding (VARTM) process with microflow vacuum control (*17*). The laminates are cured at 43 °C (110 °F) for 8 hr and post-cured at 93 °C (200 °F) for 4 hr under vacuum. Composite laminates obtained following this post-cure cycle have a nominal fiber-volume fraction $0.50 < v_f < 0.55$. After the laminates are made, 50- × 50-mm (2- × 2-in) square specimens are cut from the plate and slot ground on both sides to desired thickness for the dynamic punch shear tests. For unidirectional specimens, the thickness is 2.43 mm. For plain weave specimens, the thickness is 2.2 mm. Using various gas gun pressure values, different displacement rates are obtained.

4.   Results and Discussion

Seven unidirectional specimens and five plain weave specimens were tested under dynamic punch shear. Figure 6a shows the stresses as function of time in the IB and TT at the SGs location. Based on the 1-D wave propagation theory, stress is equal to the product of Young's modulus and measured strain. Figure 6b shows the displacements at the IB-S and the specimen-transmission tube (S-TT) interfaces using equations 2 and 3. Figure 6 represents the typical behavior for both the unidirectional and plain weave specimens. From Figure 6a, it can be seen

(a) Bar responses   (b) Interface displacements vs. time
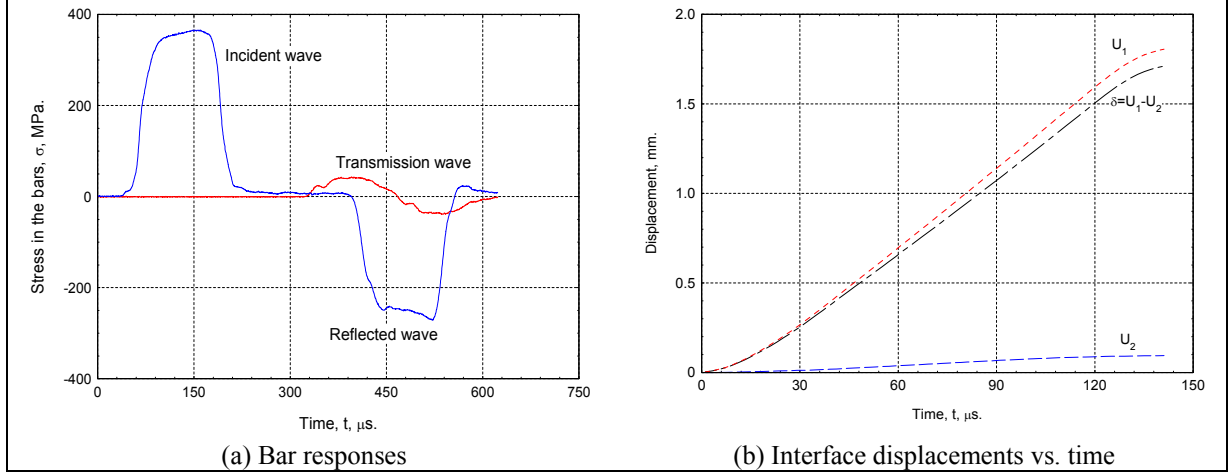
Figure 6. Dynamic punch shear results.

that not much energy is transferred to the TT. From figure 6b, it is seen that displacement u_1 is always much higher than displacement u_2.

Figure 7 shows the interface forces F_1 and F_2 (defined in equations 6 and 7), average force, and equilibrium parameter R, which are defined as $R = 2(F_1 - F_2)/(F_1 + F_2)$. When the specimens are in equilibrium, R approaches to zero. For the general SHPB test, it has been shown that the equilibrium state will be approached after the wave is reflected back and forth inside the specimen multiple times, and R becomes very low. This phenomenon is not seen for the dynamic punch shear test. From figure 7, it is seen that there is always a large difference between the two forces, and R stays >0.2 for most of the period.

(a) Unidirectional specimens   (b) Plain weave specimens
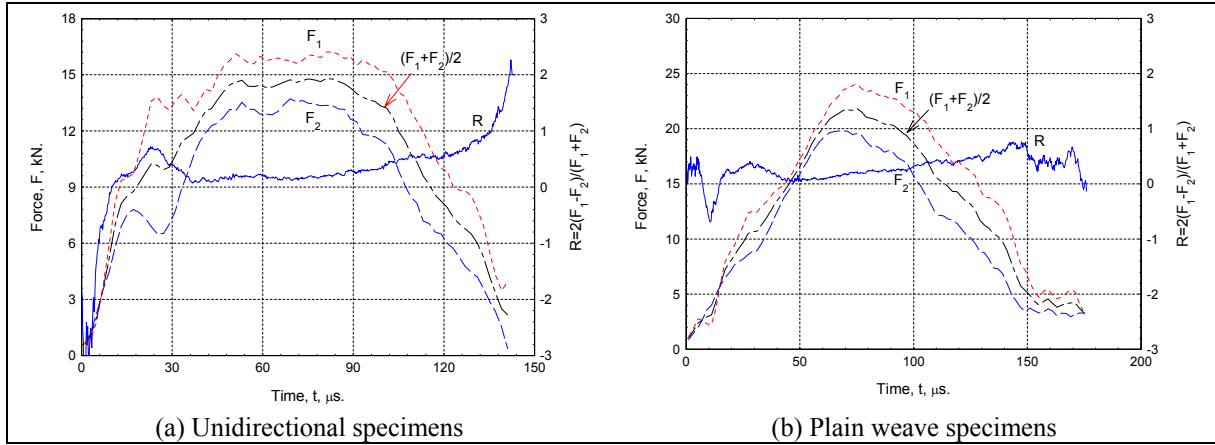
Figure 7. Interface forces and equilibrium parameter.

Comparing figure 7a and 7b, there are obvious differences between unidirectional and plain weave specimens. From figure 7a, it can be seen that F_1 and F_2 deviate from each other at early time; while for plain weave specimen, such deviation occurs much later near the maximum load. There is also a kink in the unidirectional force-vs.-time curve at early time. By examining the

failed specimens, such difference can be easily explained. Figure 8 shows two unidirectional specimens punched with different speeds (16.3 and 25.0 m/s). On the unidirectional specimens, there are many cracks along the fiber direction, while there are few such long cracks seen on the plain weave specimens. The kink point on the force-vs.-time curve corresponds to the initiation of the first matrix cracks under the shear loading. The matrix cracks continue to develop and propagate in the fiber direction under the dynamic load.

(a)   (b)   (c)   (d)

Figure 8. Unidirectional specimens after dynamic punch: (a) and (b) show front and rear sides of one specimen after low-speed punch; (c) and (d) show front and rear sides of one specimen after high-speed punch.

Figure 9 shows two failed plain weave specimens under low (18.1 m/s) and high (25.4 m/s) impact speed. It is obvious that there are no long cracks even after the high-speed impact. The matrix cracks are localized around the punched hole. The failure modes of the unidirectional composites are more complicated than the plain weave composites. While the unidirectional composites showed longitudinal splitting along the fiber direction, for the plain weave composite, matrix cracks can not extend significantly from punch perimeter region because they are arrested by the woven fabric (i.e., orthogonal tows in the fabric). When the load is increased, the area under punch is compressed first, as seen in figure 9a and 9b. When the peak load is applied, fiber tows touching the punch are sheared off, and the tows below enter into a tension state. From figure 8, it can also be seen that when the hole is punched, the region where the fiber is perpendicular to the hole boundary is cut off first (region A), while the region where the fiber is parallel to the hole boundary was cut off to a lesser degree (region B). This can also be seen from the failed specimens under higher speed punch (figure 8c and 8d).

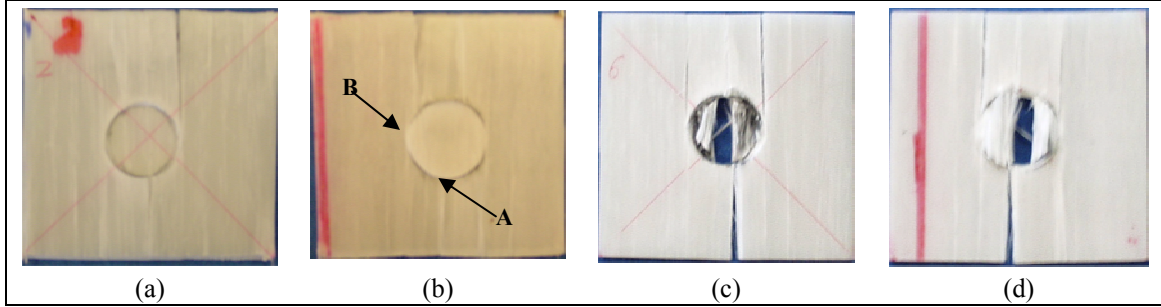(a)   (b)   (c)   (d)
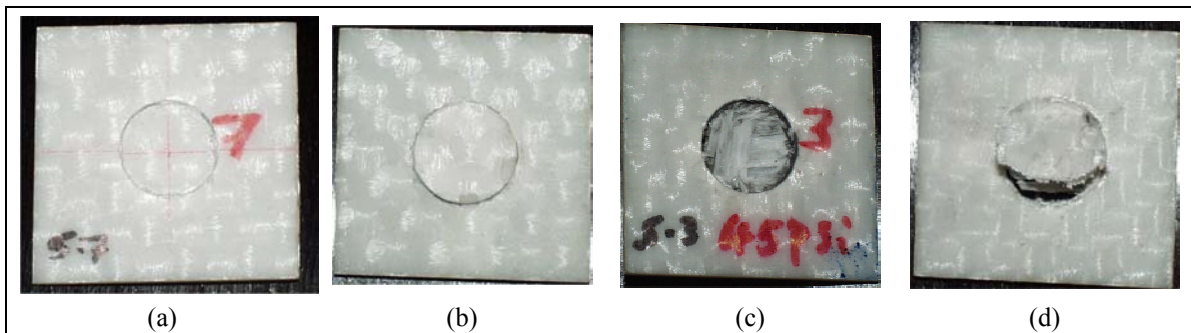
Figure 9. Plain weave specimens after dynamic punch: (a) and (b) show front and rear surfaces of one specimen after low-speed punch; (c) and (d) show front and rear surfaces of one specimen after high-speed punch.

From the viewpoint of energy, some energy is used to propagate the cracks along fiber direction in unidirectional specimens, so there is a large gap between the two interface forces. For plain weave specimens, the energy dissipation due to failure occurs around the punch region and only occurs when the peak load is reached, so the two forces remain close to each other for a longer time.

Figure 10 shows the force-vs.-displacement data for the two materials under various displacement rates. The average shear strength-vs.-strain rate is determined from the peak load as shown in figure 8. The average shear strength is defined as the maximum load divided by the shear surface area. This definition is not very accurate because at the maximum load, the materials did not completely failed, and the surface is not under uniform shear stress, so it is only an approximate representation of the complicated stress state around the hole boundary. On the other hand, this parameter still gives meaningful information. From figure 11, it is seen that plain weave material has a higher shear strength than the unidirectional material, with the difference being ~90 MPa. Secondly, the shear strength increases with the strain rate.
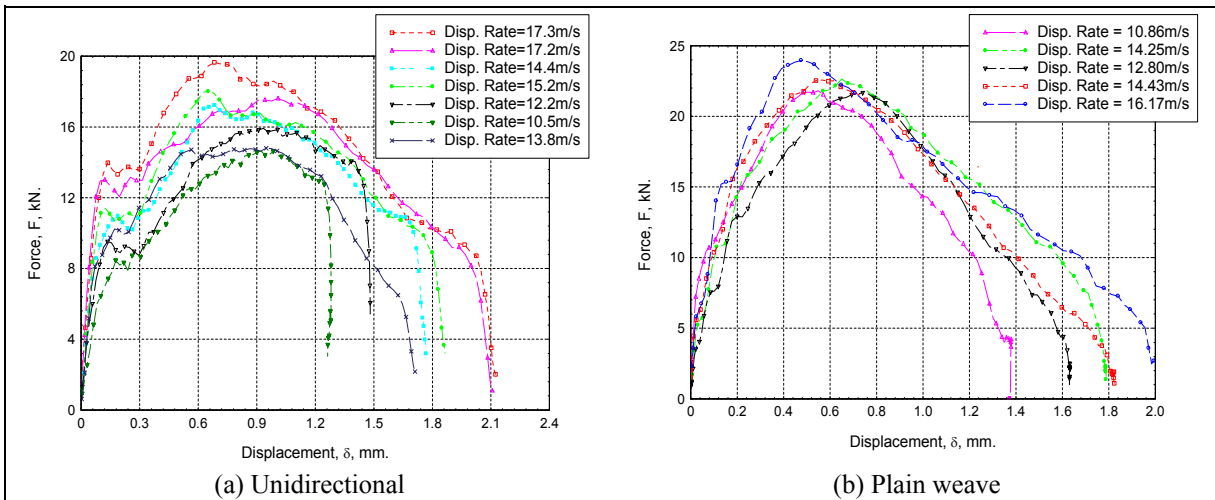
Figure 10. Force-vs.-displacement curves under various displacement rates.

8
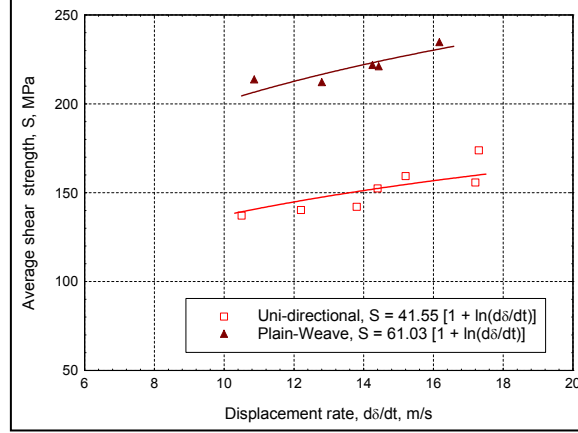
Figure 11. Average transverse shear strength of S-2
Glass/SC15 Composites as a function of
displacement rate.

5.   Conclusions

In this study, the dynamic properties of unidirectional and plain weave S-2 Glass/SC15
Composites were investigated using dynamic punch shear methodology. The experimental data
were formulated in a way, such that the forces and the displacements of the two interfaces can be
expressed as function of time. This formulation is conducive to the understanding of the shear
failure mechanism. The failure modes of the two materials were investigated, and the shear
strength was reported. The unidirectional composites under punch shear loading showed an
additional damage mode, splitting along the fiber direction, as compared to the plain weave
composites. The average transverse shear shear strength of the plain weave composite is found
higher than the unidirectional composite, and this increase is attributed to the woven structure of
the fabric. An increase in strength as a function of displacement rate is observed in both cases of
unidirectional and plain weave composites.

6. References

1. Sun, C. T.; Potti, S. V. A Simple Model to Predict Residual Velocities of Thick Composite Laminates Subjected to High Velocity Impact. *International Journal of Impact Engineering* **1996**, *18* (3), 339–353.

2. Potti, S. V; Sun, C. T. Prediction of Impact Induced Penetration and Delamination in Thick Composite Laminates. *International Journal of Impact Engineering* **1997**, *19* (1), 31–48.

3. Jeng, S. P.; Jing, H. S.; Chung, C. Predicting the Ballistic Limit for Plain Woven Glass/Epoxy Composite Laminate. *International Journal Of Impact Engineering* **1994**, *15*, 451–464.

4. Bless, S. J.; Hartman, D. R.; Hanchak, S. J. Ballistic Performance of Thick S-2 Glass Composites. *Symposium on Composite Materials in Armament Applications*, 20–22 August 1985; UDR-TR-85-88A, 1985.

5. Bless, S. J.; Hartman, D. R. Ballistic Penetration of S-2 Glass Laminates. *National SAMPE Technical Conference, Advanced Materials: The Big Payoff*, Atlantic City, NJ, 1989; Vol. 21, pp 852–866.

6. Roach, A. M.; Jones, N.; Evans, K. E. The Penetration Energy of Sandwich Panel Elements Under Static and Dynamic Loading: Part I. *Composite Structures* **1998**, *42*, 119–134.

7. Roach, A. M.; Jones, N.; Evans, K. E. The Penetration Energy of Sandwich Panel Elements under Static and Dynamic Loading: Part II. *Composite Structures* **1998**, *42*, 135–152.

8. Wang, B.; Chou, S. M. The Behavior of Laminated Composite Plates as Armor. *Journal of Materials Processing Technology* **1997**, *68*, 279–287.

9. Almohandes, A. A.; Abdel-kader, M. S.; Eleiche, A. M. Experimental Investigation of the Ballistic Resistance of Steel-Fiberglass Reinforced Polyester Laminated Plates, *Composites: Part B* **1996**, *27B*, 447–458.

10. Jacobs, M. J. N.; Van Dingenen, J. L. J. Ballistic Protection Mechanisms in Personal Armor. *Journal of Materials Science* **2001**, *36*, 3137–3142.

11. Gama, B. A.; Haque, M. J.; Paesano, A.; Gillespie, J. W., Jr.; Bogetti, T. A.; Cheeseman, B. A. Punch Shear Behavior of Thick-Section Hybrid Composite Plates. *Proceedings of the 48th International SAMPE Symposium and Exhibition*; Cohen, L. J., Ong, C-L, Arendt, C., Eds.; 2003, Vol. 48, no. 1, pp 804–813.

12. Gama, B. A.; Lopatnikov, S. L.; Gillespie, J. W., Jr. Hopkinson Bar Experimental Technique: A Critical Review. Applied Mechanics Review, submitted for publication, 2003.

13. Ren, L. B.; Larson, M.; Gama, B. A.; Gillespie, J. W., Jr. Wave Dispersion in Cylindrical Tubes: Applications to Hopkinson Pressure Bar Experimental Techniques. International Journal of Impact Engineering, submitted for publication, 2003.

14. Lifshitz, J. M.; Leber, H. Data Processing in the Split Hopkinson Pressure Bar Tests. *International Journal of Impact Engineering* **1994**, *15* (6), 723–733.

15. Mirsky, I.; Herrmann, G. Axially Symmetric Motions of Thick Cylindrical Shells. *Journal of Applied Mechanics* **1958**, *25*, 97–102.

16. Herrmann, G.; Mirsky, I. Three-Dimensional and Shell-Theory Analysis of Axially Symmetric Motions of Cylinders. *Journal of Applied Mechanics* **1956**, *23*, 563–568.

17. Gama, B. A.; Li, H.; Li, W.; Paesano, A.; Heider, D.; Gillespie, J. W., Jr. Improvement of Dimensional Tolerances During VARTM Processing. *Proceedings of 33rd International SAMPE Technical Conference*, Seattle, WA, 5–8 November, 2001; pp 1415–1427.

NO. OF COPIES	ORGANIZATION
1 (PDF Only)	DEFENSE TECHNICAL INFORMATION CENTER DTIC OCA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1	COMMANDING GENERAL US ARMY MATERIEL CMD AMCRDA TF 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	INST FOR ADVNCD TCHNLGY THE UNIV OF TEXAS AT AUSTIN 3925 W BRAKER LN STE 400 AUSTIN TX 78759-5316
1	US MILITARY ACADEMY MATH SCI CTR EXCELLENCE MADN MATH THAYER HALL WEST POINT NY 10996-1786
1	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL D DR D SMITH 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL CS IS R 2800 POWDER MILL RD ADELPHI MD 20783-1197
3	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL CI OK TL 2800 POWDER MILL RD ADELPHI MD 20783-1197
3	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL CS IS T 2800 POWDER MILL RD ADELPHI MD 20783-1197

NO. OF COPIES	ORGANIZATION
	ABERDEEN PROVING GROUND
1	DIR USARL AMSRD ARL CI OK TP (BLDG 4600)

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION

NO. OF COPIES	ORGANIZATION
1	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL SE L D SNIDER 2800 POWDER MILL RD ADELPHI MD 20783-1197
3	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL OP SD TL 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL SE R H WALLACE 2800 POWDER MILL RD ADELPHI MD 20783-1197
2	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL SS SE DS R REYZER R ATKINSON 2800 POWDER MILL RD ADELPHI MD 20783-1197
7	DIRECTOR US ARMY RESEARCH LAB AMSRD ARL WM MB A ABRAHAMIAN M BERMAN M CHOWDHURY A FRYDMAN T LI W MCINTOSH E SZYMANSKI 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	COMMANDER US ARMY MATERIEL CMD AMXMI INT 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001

NO. OF COPIES	ORGANIZATION
3	COMMANDER US ARMY ARDEC AMSTA AR CC M PADGETT J HEDDERICH H OPAT PICATINNY ARSENAL NJ 07806-5000
2	COMMANDER US ARMY ARDEC AMSTA AR AE WW E BAKER J PEARSON PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR FSE PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR TD PICATINNY ARSENAL NJ 07806-5000
13	COMMANDER US ARMY ARDEC AMSTA AR CCH A F ALTAMURA M NICOLICH M PALATHINGUL D VO R HOWELL A VELLA M YOUNG L MANOLE S MUSALLI R CARR M LUCIANO E LOGSDEN T LOUZEIRO PICATINNY ARSENAL NJ 07806-5000

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
1	COMMANDER US ARMY ARDEC AMSTA AR CCH P J LUTZ PICATINNY ARSENAL NJ 07806-5000	2	COMMANDER US ARMY ARDEC AMSTA AR CCH C H CHANIN S CHICO PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR FSF T C LIVECCHIA PICATINNY ARSENAL NJ 07806-5000	1	COMMANDER US ARMY ARDEC AMSTA AR QAC T D RIGOGLIOSO PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA ASF PICATINNY ARSENAL NJ 07806-5000	1	COMMANDER US ARMY ARDEC AMSTA AR WET T SACHAR BLDG 172 PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR QAC T C J PAGE PICATINNY ARSENAL NJ 07806-5000	1	US ARMY ARDEC INTELLIGENCE SPECIALIST AMSTA AR WEL F M GUERRIERE PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR M D DEMELLA PICATINNY ARSENAL NJ 07806-5000	10	COMMANDER US ARMY ARDEC AMSTA AR CCH B P DONADIA F DONLON P VALENTI C KNUTSON G EUSTICE K HENRY J MCNABOC G WAGNECZ R SAYER F CHANG PICATINNY ARSENAL NJ 07806-5000
3	COMMANDER US ARMY ARDEC AMSTA AR FSA A WARNASH B MACHAK M CHIEFA PICATINNY ARSENAL NJ 07806-5000		
2	COMMANDER US ARMY ARDEC AMSTA AR FSP G M SCHIKSNIS D CARLUCCI PICATINNY ARSENAL NJ 07806-5000		

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
6	COMMANDER US ARMY ARDEC AMSTA AR CCL F PUZYCKI R MCHUGH D CONWAY E JAROSZEWSKI R SCHLENNER M CLUNE PICATINNY ARSENAL NJ 07806-5000	1	COMMANDER US ARMY ARDEC PRODUCTION BASE MODERN ACTY AMSMC PBM K PICATINNY ARSENAL NJ 07806-5000
1	PM ARMS SFAE GCSS ARMS BLDG 171 PICATINNY ARSENAL NJ 07806-5000	1	COMMANDER US ARMY TACOM PM COMBAT SYSTEMS SFAE GCS CS 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY ARDEC AMSTA AR WEA J BRESCIA PICATINNY ARSENAL NJ 07806-5000	1	COMMANDER US ARMY TACOM AMSTA SF WARREN MI 48397-5000
1	PM MAS SFAE AMO MAS PICATINNY ARSENAL NJ 07806-5000	1	DIRECTOR AIR FORCE RESEARCH LAB MLLMD D MIRACLE 2230 TENTH ST WRIGHT PATTERSON AFB OH 45433-7817
1	PM MAS SFAE AMO MAS CHIEF ENGINEER PICATINNY ARSENAL NJ 07806-5000	1	OFC OF NAVAL RESEARCH J CHRISTODOULOU ONR CODE 332 800 N QUINCY ST ARLINGTON VA 22217-5600
1	PM MAS SFAE AMO MAS PS PICATINNY ARSENAL NJ 07806-5000	1	US ARMY CERL R LAMPO 2902 NEWMARK DR CHAMPAIGN IL 61822
2	PM MAS SFAE AMO MAS LC PICATINNY ARSENAL NJ 07806-5000	1	COMMANDER US ARMY TACOM PM SURVIVABLE SYSTEMS SFAE GCSS W GSI H M RYZYI 6501 ELEVEN MILE RD WARREN MI 48397-5000
2	PM MAS SFAE AMO MAS MC PICATINNY ARSENAL NJ 07806-5000		

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
1	COMMANDER US ARMY TACOM CHIEF ABRAMS TESTING SFAE GCSS W AB QT T KRASKIEWICZ 6501 ELEVEN MILE RD WARREN MI 48397-5000	14	COMMANDER US ARMY TACOM AMSTA TR R R MCCLELLAND D THOMAS J BENNETT D HANSEN AMSTA JSK S GOODMAN J FLORENCE
1	COMMANDER WATERVLIET ARSENAL SMCWV QAE Q B VANINA BLDG 44 WATERVLIET NY 12189-4050		K IYER D TEMPLETON A SCHUMACHER AMSTA TR D D OSTBERG L HINOJOSA B RAJU
1	TNG DOC & CBT DEV ATZK TDD IRSA A POMEY FT KNOX KY 40121		AMSTA CS SF H HUTCHINSON F SCHWARZ WARREN MI 48397-5000
2	HQ IOC TANK AMMUNITION TEAM AMSIO SMT R CRAWFORD W HARRIS ROCK ISLAND IL 61299-6000	14	BENET LABORATORIES AMSTA AR CCB R FISCELLA M SOJA E KATHE M SCAVULO G SPENCER P WHEELER
2	COMMANDER US ARMY AMCOM AVIATION APPLIED TECH DIR J SCHUCK FT EUSTIS VA 23604-5577		S KRUPSKI J VASILAKIS G FRIAR R HASENBEIN AMSTA CCB R S SOPOK
1	NVL SURFACE WARFARE CTR DAHLGREN DIV CODE G06 DAHLGREN VA 22448		E HYLAND D CRAYON R DILLON WATERVLIET NY 12189-4050
2	US ARMY CORPS OF ENGR CERD C T LIU CEW ET T TAN 20 MASSACHUSETTS AVE NW WASHINGTON DC 20314	1	USA SBCCOM PM SOLDIER SPT AMSSB PM RSS A J CONNORS KANSAS ST NATICK MA 01760-5057
1	US ARMY COLD REGIONS RSCH & ENGRNG LAB P DUTTA 72 LYME RD HANOVER NH 03755	2	USA SBCCOM MATERIAL SCIENCE TEAM AMSSB RSS J HERBERT M SENNETT KANSAS ST NATICK MA 01760-5057

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
2	OFC OF NAVAL RESEARCH D SIEGEL CODE 351 J KELLY 800 N QUINCY ST ARLINGTON VA 22217-5660	8	US ARMY SBCCOM SOLDIER SYSTEMS CENTER BALLISTICS TEAM J WARD W ZUKAS P CUNNIFF J SONG MARINE CORPS TEAM J MACKIEWICZ BUS AREA ADVOCACY TEAM W HASKELL AMSSB RCP SS W NYKVIST S BEAUDOIN KANSAS ST NATICK MA 01760-5019
1	NVL SURFACE WARFARE CTR TECH LIBRARY CODE 323 17320 DAHLGREN RD DAHLGREN VA 22448		
1	NVL SURFACE WARFARE CTR CRANE DIVISION M JOHNSON CODE 20H4 LOUISVILLE KY 40214-5245		
2	NVL SURFACE WARFARE CTR U SORATHIA C WILLIAMS CD 6551 9500 MACARTHUR BLVD WEST BETHESDA MD 20817	7	US ARMY RESEARCH OFC A CROWSON H EVERETT J PRATER G ANDERSON D STEPP D KISEROW J CHANG PO BOX 12211 RESEARCH TRIANGLE PARK NC 27709-2211
2	COMMANDER NVL SURFACE WARFARE CTR CARDEROCK DIVISION R PETERSON CODE 2020 M CRITCHFIELD CODE 1730 BETHESDA MD 20084		
8	DIRECTOR US ARMY NATIONAL GROUND INTELLIGENCE CTR D LEITER MS 404 M HOLTUS MS 301 M WOLFE MS 307 S MINGLEDORF MS 504 J GASTON MS 301 W GSTATTENBAUER MS 304 R WARNER MS 305 J CRIDER MS 306 2055 BOULDERS RD CHARLOTTESVILLE VA 22911-8318	1	AFRL MLBC 2941 P ST RM 136 WRIGHT PATTERSON AFB OH 45433-7750
		8	NVL SURFACE WARFARE CTR J FRANCIS CODE G30 D WILSON CODE G32 R D COOPER CODE G32 J FRAYSSE CODE G33 E ROWE CODE G33 T DURAN CODE G33 L DE SIMONE CODE G33 R HUBBARD CODE G33 DAHLGREN VA 22448
1	NAVAL SEA SYSTEMS CMD D LIESE 1333 ISAAC HULL AVE SE 1100 WASHINGTON DC 20376-1100		
1	EXPEDITIONARY WARFARE DIV N85 F SHOUP 2000 NAVY PENTAGON WASHINGTON DC 20350-2000	1	NVL SURFACE WARFARE CTR CARDEROCK DIVISION R CRANE CODE 6553 9500 MACARTHUR BLVD WEST BETHESDA MD 20817-5700

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
1	AFRL MLSS R THOMSON 2179 12TH ST RM 122 WRIGHT PATTERSON AFB OH 45433-7718	2	SERDP PROGRAM OFC PM P2 C PELLERIN B SMITH 901 N STUART ST STE 303 ARLINGTON VA 22203
2	AFRL F ABRAMS J BROWN BLDG 653 2977 P ST STE 6 WRIGHT PATTERSON AFB OH 45433-7739	1	OAK RIDGE NATIONAL LABORATORY R M DAVIS PO BOX 2008 OAK RIDGE TN 37831-6195
5	DIRECTOR LLNL R CHRISTENSEN S DETERESA F MAGNESS M FINGER MS 313 M MURPHY L 282 PO BOX 808 LIVERMORE CA 94550	1	OAK RIDGE NATIONAL LABORATORY C EBERLE MS 8048 PO BOX 2008 OAK RIDGE TN 37831
1	AFRL MLS OL L COULTER 5851 F AVE BLDG 849 RM AD1A HILL AFB UT 84056-5713	3	DIRECTOR SANDIA NATIONAL LABS APPLIED MECHANICS DEPT MS 9042 J HANDROCK Y R KAN J LAUFFER PO BOX 969 LIVERMORE CA 94551-0969
1	DIRECTOR LOS ALAMOS NATIONAL LAB F L ADDESSIO T 3 MS 5000 PO BOX 1633 LOS ALAMOS NM 87545	1	OAK RIDGE NATIONAL LABORATORY C D WARREN MS 8039 PO BOX 2008 OAK RIDGE TN 37831
1	OSD JOINT CCD TEST FORCE OSD JCCD R WILLIAMS 3909 HALLS FERRY RD VICKSBURG MS 29180-6199	4	NIST M VANLANDINGHAM MS 8621 J CHIN MS 8621 J MARTIN MS 8621 D DUTHINH MS 8611 100 BUREAU DR GAITHERSBURG MD 20899
3	DARPA M VANFOSSEN S WAX L CHRISTODOULOU 3701 N FAIRFAX DR ARLINGTON VA 22203-1714	1	HYDROGEOLOGIC INC SERDP ESTCP SPT OFC S WALSH 1155 HERNDON PKWY STE 900 HERNDON VA 20170

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
3	NASA LANGLEY RSCH CTR AMSRL VS W ELBER MS 266 F BARTLETT JR MS 266 G FARLEY MS 266 HAMPTON VA 23681-0001	1	DIRECTOR DEFENSE INTLLGNC AGNCY TA 5 K CRELLING WASHINGTON DC 20310
1	NASA LANGLEY RSCH CTR T GATES MS 188E HAMPTON VA 23661-3400	1	ADVANCED GLASS FIBER YARNS T COLLINS 281 SPRING RUN LANE STE A DOWNINGTON PA 19335
1	FHWA E MUNLEY 6300 GEORGETOWN PIKE MCLEAN VA 22101	1	COMPOSITE MATERIALS INC D SHORTT 19105 63 AVE NE PO BOX 25 ARLINGTON WA 98223
1	USDOT FEDERAL RAILRD M FATEH RDV 31 WASHINGTON DC 20590	1	JPS GLASS L CARTER PO BOX 260 SLATER RD SLATER SC 29683
3	CYTEC FIBERITE R DUNNE D KOHLI R MAYHEW 1300 REVOLUTION ST HAVRE DE GRACE MD 21078	1	COMPOSITE MATERIALS INC R HOLLAND 11 JEWEL CT ORINDA CA 94563
1	DIRECTOR NTNL GRND INTLLGNC CTR IANG TMT 2055 BOULDERS RD CHARLOTTESVILLE VA 22911-8318	1	COMPOSITE MATERIALS INC C RILEY 14530 S ANSON AVE SANTA FE SPRINGS CA 90670
1	SIOUX MFG B KRIEL PO BOX 400 FT TOTTEN ND 58335	2	SIMULA J COLTMAN R HUYETT 10016 S 51ST ST PHOENIX AZ 85044
2	3TEX CORPORATION A BOGDANOVICH J SINGLETARY 109 MACKENAN DR CARY NC 27511	2	PROTECTION MATERIALS INC M MILLER F CRILLEY 14000 NW 58 CT MIAMI LAKES FL 33014
1	3M CORPORATION J SKILDUM 3M CENTER BLDG 60 IN 01 ST PAUL MN 55144-1000	2	FOSTER MILLER M ROYLANCE W ZUKAS 195 BEAR HILL RD WALTHAM MA 02354-1196

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
1	ROM DEVELOPMENT CORP R O MEARA 136 SWINEBURNE ROW BRICK MARKET PLACE NEWPORT RI 02840	8	ALLIANT TECHSYSTEMS INC C CANDLAND MN11 2830 C AAKHUS MN11 2830 B SEE MN11 2439 N VLAHAKUS MN11 2145 R DOHRN MN11 2830 S HAGLUND MN11 2439 M HISSONG MN11 2830 D KAMDAR MN11 2830 600 SECOND ST NE HOPKINS MN 55343-8367
2	TEXTRON SYSTEMS T FOLTZ M TREASURE 1449 MIDDLESEX ST LOWELL MA 01851		
1	O GARA HESS & EISENHARDT M GILLESPIE 9113 LESAINT DR FAIRFIELD OH 45014	1	SAIC M PALMER 1410 SPRING HILL RD STE 400 MS SH4 5 MCLEAN VA 22102
2	MILLIKEN RSCH CORP H KUHN M MACLEOD PO BOX 1926 SPARTANBURG SC 29303	1	R FIELDS 4680 OAKCREEK ST APT 206 ORLANDO FL 32835
1	CONNEAUGHT INDUSTRIES INC J SANTOS PO BOX 1425 COVENTRY RI 02816	1	APPLIED COMPOSITES W GRISCH 333 NORTH SIXTH ST ST CHARLES IL 60174
1	ARMTEC DEFENSE PRODUCTS S DYER 85 901 AVE 53 PO BOX 848 COACHELLA CA 92236	1	CUSTOM ANALYTICAL ENG SYS INC A ALEXANDER 13000 TENSOR LANE NE FLINTSTONE MD 21530
1	NATIONAL COMPOSITE CENTER T CORDELL 2000 COMPOSITE DR KETTERING OH 45420	1	AAI CORPORATION DR N B MCNELLIS PO BOX 126 HUNT VALLEY MD 21030-0126
3	PACIFIC NORTHWEST LAB M SMITH G VAN ARSDALE R SHIPPELL PO BOX 999 RICHLAND WA 99352	1	OFC DEPUTY UNDER SEC DEFNS J THOMPSON 1745 JEFFERSON DAVIS HWY CRYSTAL SQ 4 STE 501 ARLINGTON VA 22202
3	ALLIANT TECHSYSTEMS INC J CONDON E LYNAM J GERHARD WV01 16 STATE RT 956 PO BOX 210 ROCKET CENTER WV 26726-0210	1	PROJECTILE TECHNOLOGY INC 515 GILES ST HAVRE DE GRACE MD 21078
		1	HEXCEL INC R BOE PO BOX 18748 SALT LAKE CITY UT 84118

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
5	NORTHROP GRUMMAN B IRWIN K EVANS D EWART A SHREKENHAMER J MCGLYNN BLDG 160 DEPT 3700 1100 WEST HOLLYVALE ST AZUSA CA 91701	1	PRATT & WHITNEY C WATSON 400 MAIN ST MS 114 37 EAST HARTFORD CT 06108
1	HERCULES INC HERCULES PLAZA WILMINGTON DE 19894	1	AEROSPACE CORP G HAWKINS M4 945 2350 E EL SEGUNDO BLVD EL SEGUNDO CA 90245
1	BRIGS COMPANY J BACKOFEN 2668 PETERBOROUGH ST HERNDON VA 22071-2443	2	CYTEC FIBERITE M LIN W WEB 1440 N KRAEMER BLVD ANAHEIM CA 92806
1	ZERNOW TECHNICAL SERVICES L ZERNOW 425 W BONITA AVE STE 208 SAN DIMAS CA 91773	2	UDLP G THOMAS M MACLEAN PO BOX 58123 SANTA CLARA CA 95052
1	GENERAL DYNAMICS OTS L WHITMORE 10101 NINTH ST NORTH ST PETERSBURG FL 33702	1	UDLP WARREN OFC A LEE 31201 CHICAGO RD SOUTH SUITE B102 WARREN MI 48093
2	GENERAL DYNAMICS OTS FLINCHBAUGH DIV K LINDE T LYNCH PO BOX 127 RED LION PA 17356	2	UDLP R BRYNSVOLD P JANKE MS 170 4800 EAST RIVER RD MINNEAPOLIS MN 55421-1498
1	GKN WESTLAND AEROSPACE D OLDS 450 MURDOCK AVE MERIDEN CT 06450-8324	2	BOEING ROTORCRAFT P MINGURT P HANDEL 800 B PUTNAM BLVD WALLINGFORD PA 19086
5	SIKORSKY AIRCRAFT G JACARUSO T CARSTENSAN B KAY S GARBO MS S330A J ADELMANN 6900 MAIN ST PO BOX 9729 STRATFORD CT 06497-9729	1	LOCKHEED MARTIN SKUNK WORKS D FORTNEY 1011 LOCKHEED WAY PALMDALE CA 93599-2502
		1	LOCKHEED MARTIN R FIELDS 5537 PGA BLVD SUITE 4516 ORLANDO FL 32839

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
1	NORTHRUP GRUMMAN CORP ELECTRONIC SENSORS & SYSTEMS DIV E SCHOCH MS V 16 1745A W NURSERY RD LINTHICUM MD 21090	1	SAIC G CHRYSSOMALLIS 8500 NORMANDALE LAKE BLVD SUITE 1610 BLOOMINGTON MN 55437-3828
1	GDLS DIVISION D BARTLE PO BOX 1901 WARREN MI 48090	1	UCLA MANE DEPT ENGR IV H T HAHN LOS ANGELES CA 90024-1597
2	GDLS D REES M PASIK PO BOX 2074 WARREN MI 48090-2074	2	UNIV OF DAYTON RESEARCH INST R Y KIM A K ROY 300 COLLEGE PARK AVE DAYTON OH 45469-0168
1	GDLS MUSKEGON OPERATIONS M SOIMAR 76 GETTY ST MUSKEGON MI 49442	1	UMASS LOWELL PLASTICS DEPT N SCHOTT 1 UNIVERSITY AVE LOWELL MA 01854
1	GENERAL DYNAMICS AMPHIBIOUS SYS SURVIVABILITY LEAD G WALKER 991 ANNAPOLIS WAY WOODBRIDGE VA 22191	1	IIT RESEARCH CENTER D ROSE 201 MILL ST ROME NY 13440-6916
6	INST FOR ADVANCED TECH H FAIR I MCNAB P SULLIVAN S BLESS W REINECKE C PERSAD 3925 W BRAKER LN STE 400 AUSTIN TX 78759-5316	1	GA TECH RSCH INST GA INST OF TCHNLGY P FRIEDERICH ATLANTA GA 30392
		1	MICHIGAN ST UNIV MSM DEPT R AVERILL 3515 EB EAST LANSING MI 48824-1226
1	ARROW TECH ASSOC 1233 SHELBURNE RD STE D8 SOUTH BURLINGTON VT 05403-7700	1	UNIV OF WYOMING D ADAMS PO BOX 3295 LARAMIE WY 82071
1	R EICHELBERGER CONSULTANT 409 W CATHERINE ST BEL AIR MD 21014-3613	2	PENN STATE UNIV R MCNITT C BAKIS 212 EARTH ENGR SCIENCES BLDG UNIVERSITY PARK PA 16802

NO. OF COPIES	ORGANIZATION	NO. OF COPIES	ORGANIZATION
1	PENN STATE UNIV R S ENGEL 245 HAMMOND BLDG UNIVERSITY PARK PA 16801	1	DEPT OF MATERIALS SCIENCE & ENGINEERING UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN J ECONOMY 1304 WEST GREEN ST 115B URBANA IL 61801
1	PURDUE UNIV SCHOOL OF AERO & ASTRO C T SUN W LAFAYETTE IN 47907-1282	1	UNIV OF MARYLAND DEPT OF AEROSPACE ENGNRNG A J VIZZINI COLLEGE PARK MD 20742
1	STANFORD UNIV DEPT OF AERONAUTICS & AEROBALLISTICS S TSAI DURANT BLDG STANFORD CA 94305	1	DREXEL UNIV A S D WANG 3141 CHESTNUT ST PHILADELPHIA PA 19104
1	UNIV OF MAINE ADV STR & COMP LAB R LOPEZ ANIDO 5793 AEWC BLDG ORONO ME 04469-5793	3	UNIV OF TEXAS AT AUSTIN CTR FOR ELECTROMECHANICS J PRICE A WALLS J KITZMILLER 10100 BURNET RD AUSTIN TX 78758-4497
1	JOHNS HOPKINS UNIV APPLIED PHYSICS LAB P WIENHOLD 11100 JOHNS HOPKINS RD LAUREL MD 20723-6099	3	VA POLYTECHNICAL INST & STATE UNIV DEPT OF ESM M W HYER K REIFSNIDER R JONES BLACKSBURG VA 24061-0219
1	UNIV OF DAYTON J M WHITNEY COLLEGE PARK AVE DAYTON OH 45469-0240	1	SOUTHWEST RSCH INST ENGR & MATL SCIENCES DIV J RIEGEL 6220 CULEBRA RD PO DRAWER 28510 SAN ANTONIO TX 78228-0510
1	NORTH CAROLINA STATE UNIV CIVIL ENGINEERING DEPT W RASDORF PO BOX 7908 RALEIGH NC 27696-7908		
1	BATELLE NATICK OPERATIONS B HALPIN 313 SPEEN ST NATICK MA 01760		ABERDEEN PROVING GROUND
5	UNIV OF DELAWARE CTR FOR COMPOSITE MTRLS J GILLESPIE M SANTARE S YARLAGADDA S ADVANI D HEIDER 201 SPENCER LABORATORY NEWARK DE 19716	1	US ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY P DIETZ 392 HOPKINS RD AMXSY TD APG MD 21005-5071

NO. OF COPIES	ORGANIZATION		NO. OF COPIES	ORGANIZATION

NO. OF COPIES	ORGANIZATION
1	LTD R MARTIN MERL TAMWORTH RD HERTFORD SG13 7DG UK
1	SMC SCOTLAND P W LAY DERA ROSYTH ROSYTH ROYAL DOCKYARD DUNFERMLINE FIFE KY 11 2XR UK
1	CIVIL AVIATION ADMINSTRATION T GOTTESMAN PO BOX 8 BEN GURION INTRNL AIRPORT LOD 70150 ISRAEL
1	AEROSPATIALE S ANDRE A BTE CC RTE MD132 316 ROUTE DE BAYONNE TOULOUSE 31060 FRANCE
1	DRA FORT HALSTEAD P N JONES SEVEN OAKS KENT TN 147BP UK
1	SWISS FEDERAL ARMAMENTS WKS W LANZ ALLMENDSTRASSE 86 3602 THUN SWITZERLAND
1	DYNAMEC RESEARCH AB AKE PERSSON BOX 201 SE 151 23 SODERTALJE SWEDEN

NO. OF COPIES	ORGANIZATION
1	ISRAEL INST OF TECHNOLOGY S BODNER FACULTY OF MECHANICAL ENGR HAIFA 3200 ISRAEL
1	DSTO WEAPONS SYSTEMS DIVISION N BURMAN RLLWS SALISBURY SOUTH AUSTRALIA 5108 AUSTRALIA
1	DEF RES ESTABLISHMENT VALCARTIER A DUPUIS 2459 BLVD PIE XI NORTH VALCARTIER QUEBEC CANADA PO BOX 8800 COURCELETTE GOA IRO QUEBEC CANADA
1	ECOLE POLYTECH J MANSON DMX LTC CH 1015 LAUSANNE SWITZERLAND
1	TNO DEFENSE RESEARCH R IJSSELSTEIN ACCOUNT DIRECTOR R&D ARMEE PO BOX 6006 2600 JA DELFT THE NETHERLANDS
2	FOA NATL DEFENSE RESEARCH ESTAB DIR DEPT OF WEAPONS & PROTECTION B JANZON R HOLMLIN S 172 90 STOCKHOLM SWEDEN

    2   DEFENSE TECH & PROC
         AGENCY GROUND
         I CREWTHER
         GENERAL HERZOG HAUS
         3602 THUN
         SWITZERLAND

    1   MINISTRY OF DEFENCE
         RAFAEL
         ARMAMENT DEVELOPMENT
         AUTH
         M MAYSELESS
         PO BOX 2250
         HAIFA 31021
         ISRAEL

    1   TNO DEFENSE RESEARCH
         I H PASMAN
         POSTBUS 6006
         2600 JA DELFT
         THE NETHERLANDS

    1   B HIRSCH
         TACHKEMONY ST 6
         NETAMUA 42611
         ISRAEL

    1   DEUTSCHE AEROSPACE AG
         DYNAMICS SYSTEMS
         M HELD
         PO BOX 1340
         D 86523 SCHROBENHAUSEN
         GERMANY

INTENTIONALLY LEFT BLANK.